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Ice Velocity Response to Surface Melt and Lake Drainages at a Land-Terminating Margin of the Greenland Ice Sheet

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Approximately 50% of current mass loss from the Greenland Ice Sheet is from ice dynamics. It is important to understand the processes controlling ice dynamics to better calculate current rates of mass loss and predict rates into the future. Previous work has shown that both surface runoff and surface lake drainages control subglacial drainage development and therefore seasonal and annual velocities of the ice sheet, although few studies have considered these together. Here we analyse monthly patterns of runoff, lake drainages and ice velocities across a 6 753 km^2 land terminating part of the ice sheet between 2016 and 2021. We find that annual runoff is inversely correlated with annual velocity across the study area, supporting previous work showing the importance of subglacial drainage development in driving down water pressures and therefore basal sliding speeds. We also show that rapid surface lake drainages (a surrogate for moulin formation by hydrofracture) have an impact superimposed on the runoff control. 2016 and 2019 have comparably high annual runoff totals but the former experiences three times more rapid lake drainages than the latter, resulting in greater depressurisation of the subglacial drainage system, greater net summer slowdown and lower annual velocities. We also demonstrate 'interannual subglacial memory' with years succeeding high runoff years showing net summer speedup, higher winter velocities and higher annual velocities than might otherwise be expected. We identify, therefore, high runoff 'depressurisation' years and subsequent 'recharge' years, with effects on seasonal and annual glacier velocities. Finally, we see localised impacts of lake drainages on spatial patterns of net summer speed up or slowdown, with lake drainages acting to depressurise cavities causing local slowdown in some instances, or recharge cavities causing local speedup in others. These processes should be considered for modelling of the future impacts of climate-controlled runoff on ice sheet dynamics and mass balance.